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A SURVEY OF LIFE-DETECTION EXPERIMENTS FOR MARS

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by

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The Life-Detection Experiments Team

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, Calif.

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SUMMARY

The results of a survey of life-detection experiments for Mars are presented. This survey was made by a team at the Ames Research Center in response to a request by the Bioscience Office in the NASA Office of Space Sciences. The survey is intended to determine the status and support requirements of a variety of experiments. Particular attention is given to ascertaining which experiments may be available and suitable for the 1966 Mars Mariner mission. The experiments covered in the survey include the Gas Chromatograph, Gulliver, the "J" Band, the Mass Spectrometer, the Multivator, Optical Rotation, the Wolf Trap, and several others.

Of the experiments covered by the survey, it appears that only three have a reasonable chance of meeting the schedules imposed by the 1966 Mars Mariner mission. These three are the Gas Chromatograph, Gulliver, and Multivator (or Minivator). For the Multivator, however, there is no complete experiment and the other two have sampling problems.

The most serious problems uncovered in the survey are of a universal nature common to virtually all experiments. First, no adequate sample collection, concentration, or preparation devices have been devised. Without prompt attention, this lack may actually prevent the inclusion of a life-detection experiment on the 1966 mission. It was also noted that instrument prototype development is being delayed by lack of a clear definition of the experiment-vehicle interface.

Inability to control the landing site and the large uncertainties existing in knowledge of the Martian atmosphere, particularly surface pressure, appear to be major difficulties which cannot be resolved for the 1966 mission. Both factors have large effects on the probability of success of a life-detection experiment. The uncertainties are so large, in fact, that life-detection experiments may not be suitable candidates for a Mariner mission and may, in fact, be more appropriate to a Voyager mission.

If it is ultimately considered desirable to include a life-detection experiment on the 1966 Mariner, it would appear that it should be a device which is not dependent on growth or metabolism. Use of such devices introduces the added requirement and uncertainty that a suitable ecology for an unknown organism must be provided.

INTRODUCTION

The search for extraterrestrial life has been called the most provocative aspect of the program for the exploration of space. Certainly the discovery of such life would be a major accomplishment in the program. In recognition of the importance of the task, scientists throughout the country have conceived and proposed various experiments which could be used to detect life on other planets. In order to accomplish this objective, however, these conceptual experiments must be evolved into flight-qualified instrument hardware. This task is difficult and it may easily delay the development of an experiment. Such delays become more important as the time approaches for the final design freeze on a transporting spacecraft. One of the first vehicles to carry a life-detection experiment will probably be the 1966 Mariner to Mars. The schedule for this vehicle is such that the time is rapidly approaching when the selection of its experiments must be made.

For these reasons the Bioscience Office in the NASA Office of Space Sciences requested that a survey be made of life-detection experiments and, in particular, of those which might be candidates for this 1966 Mars Mariner mission. The purpose specified for this survey was to determine both the current status and the future support requirements of the life-detection experiments. To conduct this survey, the Office of Space Sciences requested the aid of the Ames Research Center. In response to this request, a team was formed at Ames with representation from the Exobiology, Instrument Research, Mission Analysis, Space Sciences, Systems Engineering, and Technical Planning Divisions. This team organized and conducted the requested survey of experiments and, in addition, examined probable candidates for the transport vehicles.

The present report contains the results obtained by the team. In the sections that follow, the methods employed in the surveys and analyses will be described first. This description will be followed by the results of the survey of experiments and then by the results of the survey of vehicles. A general discussion of the results obtained by the team will then be presented.

MEMBERS, METHODS, AND GUIDELINES

Team Membership

The Life-Detection Experiments Team that was formed at the Ames Research Center had as members the following:

Mr. C. A. Syvertson, Chairman

Science	Engineering
Dr. Richard S. Young, Vice Chairman	Mr. Raymond C. Savin, Vice Chairman
Dr. Lawrence I. Hochstein	Mr. George W. Clemens, Jr.
Mr. Jacob H. Miller	Mr. James N. Cole
Mr. Vance Oyama	Mr. Frederick A. Demele
Dr. Robert B. Painter	Mr. Ralph W. Donaldson, Jr.
Dr. Leonard P. Zill	Mr. Richard O. Fimmel
	Mr. George H. Holdaway

Copies of the correspondence and memorandum which led to and accomplished the establishment of this team are contained for the record in appendix A. It will be noted that some changes in team personnel were required to complete the task assigned.

Survey Methods

As indicated earlier, the Ames team conducted two surveys, one to determine the status and support requirements of proposed life-detection experiments and the second to examine possible transport vehicles.

Experiments.- The survey of life-detection experiments was conducted by three two-man groups who visited appropriate experimenters and institutions. These two-man groups had one representative with a background in life sciences and one with a background in physical sciences. They used as a guide for their collection of information the questionnaire reproduced in appendix A. The use of the questionnaire provided a method for obtaining a consistent set of information for all experiments. In addition, it was forwarded to all people visited in advance of the visits to assist in the preparation and collection of information. The two-man groups and their respective contacts were as follows:

Dr. Lawrence I. Hochstein
Mr. James N. Cole

1. Gulliver

   Dr. Gilbert Levin
   Resources Research, Inc.
   1246 Taylor Street, N. W.
   Washington 11, D. C.

2. Wolf Trap

   Dr. Wolf Vishniac
   Department of Biology
   University of Rochester
   Rochester 20, New York

3. Optical Rotation

   Dr. Ira Blei
   Melpar, Inc.
   3000 Arlington Blvd.
   Falls Church, Virginia

4. Ultraviolet Spectrophotometry

   Dr. Ira Blei
   Melpar, Inc.
   3000 Arlington Blvd.
   Falls Church, Virginia

Dr. Robert B. Painter
Mr. Jacob H. Miller

1. Vidicon Microscope

   Dr. Joshua Lederberg
   Department of Genetics
   Medical School
   Stanford University
   Stanford, California

   Dr. Gerald A. Soffen
   Jet Propulsion Laboratory
   4800 Oak Grove Drive
   Pasadena, California

2. <u>Multivator</u>

   Dr. Joshua Lederberg
   Department of Genetics
   Medical School
   Stanford University
   Stanford, California

3. <u>Minivator</u>

   Mr. Jerry L. Stuart
   Jet Propulsion Laboratory
   4800 Oak Grove Drive
   Pasadena, California

4. <u>"J" Band</u>

   Dr. R. E. Kay
   Aeronutronic Division
   Ford Motor Company
   Ford Road
   Newport Beach, California

Dr. Leonard P. Zill
Mr. Ralph W. Donaldson, Jr.

1. <u>Gas Chromatograph</u>

   Mr. George Hobby
   Jet Propulsion Laboratory
   4800 Oak Grove Drive
   Pasadena, California

   Mr. Vance Oyama
   Ames Research Center
   Moffett Field, California

2. <u>Mass Spectrometer</u>

   Dr. Klaus Biemann
   Department of Chemistry
   Massachusetts Institute of Technology
   Cambridge, Massachusetts

3. <u>Microscopic System</u>

   Dr. Robert D. Allen
   Department of Biology
   Princeton University
   Princeton, New Jersey

Since several of these experiments were in an early state of development, the contact was limited, in some cases to a telephone call. For these experiments then the results of the survey will be treated in a common, brief discussion.

Vehicles.- The purpose of the survey of vehicles was to determine, approximately at least, what are the important characteristics of vehicles which might transport a life-detection experiment to Mars. It was felt that this survey was an essential feature of the task assigned to the team because any decision regarding the availability of an experiment will be influenced by the constraints imposed by the transport vehicle. The survey of vehicles was not, however, as formal and comprehensive as the survey of experiments. Contacts were made at the Goddard Space Flight Center, the Lewis Research Center, and the Jet Propulsion Laboratory. From the information gathered in these contacts and from independent analyses, the weight and performance characteristics of a family of transport vehicles were determined. This information will be discussed in greater detail in a later section.

The members of the team who assisted in the preparation of the survey of vehicles were:

Mr. R. C. Savin
Mr. G. W. Clemens, Jr.
Mr. F. A. Demele
Mr. G. H. Holdaway

Guidelines

Most of the guidelines employed by the team in the conduct of its task are evident from the foregoing description of the surveys that were made. In addition, however, several general constraints were applied. The basic list of experiments which were covered in the survey was obtained from the Bioscience Office in NASA Headquarters. Although no concerted effort was made to expand greatly on this list, some additional experiments were covered briefly in the survey. As will become evident, most of the added experiments, being often newly conceived, will probably be unable to meet the schedule required by a 1966 Mars mission. As a measure of availability of any experiment, a target schedule was set down for reference purposes. As well as the team could estimate this schedule, it is:

Deadline	Status	Definition of Status
September 1963	Functional breadboard	The functional feasibility of the experiment must be demonstrated with a breadboard instrument which need not meet flight weights and sizes.
December 1963	Flight-size breadboard	This instrument must meet the requirements of the previous breadboard and, in addition, it must meet flight restrictions as to weight and size. It does not, however, have to meet other environmental constraints.
March 1964	First prototype	This instrument should be designed to satisfy all environmental and operational constraints.
June 1964	Last prototype	This instrument must demonstrate an ability to meet all environmental and operational constraints.
September 1964	Final instrument type approval tested	An instrument identical to the final flight article shall have passed all required tests.

It might be added that to the best knowledge of the team members no experiments were omitted from the survey for which any significant amount of work has been accomplished.

It should be further noted that it became evident early in the work of the team that the basic problem would not be to select from a variety of experiments for the 1966 mission. Rather, it appeared that the scheduling and payload restrictions for this mission could very well eliminate from consideration most of the experiments. For this reason, the work of the team was expanded sufficiently to cover later mission dates and larger permissible payloads. In estimating the larger payloads, attention was restricted to launch systems now existing or now under development. These systems were the Atlas-Agena, Atlas-Centaur, Saturn I, and Saturn I-B.

SURVEY OF EXPERIMENTS

The detailed results obtained during the survey of life-detection experiments, in particular the results obtained in response to the survey questionnaire, are contained in the several subsections of appendix B. The material in this appendix is exclusively that collected in the survey and contains no comment by the survey team. Part of the collected material is condensed and summarized in tables I and II. Table I presents a summary picture of the status, availability, and funding and manpower requirements. Table II summarizes the available information on the physical characteristics of the flight instruments including such items as weight, size, and power requirements. Some of this material will also be included in the brief narrative summaries which follow immediately. The primary purpose of this narrative material, however, is to describe the function of each experiment and to point up those factors which may affect its suitability for the 1966 mission. Those experiments for which information is generally lacking will be discussed in a single common subsection presented later.

Gas Chromatograph

The Gas Chromatograph is being developed at the Jet Propulsion Laboratory in Pasadena in the Space Science Division (Chief: Dr. Robert V. Meghreblian). Outside experimenters include Dr. Sanford Lipsky at Yale University and Dr. James Lovelock at Baylor University. The basic principle by which the experiment works is the qualitative and quantitative separation and identification of the pyrolysis products of organic molecules found in biological systems. Such a system is based on gas-liquid chromatography depending on varying distribution coefficients to attain separations and detection by several sensitive devices. Such a system would detect the presence or absence of organic matter in a soil sample collected from the Martian surface, regardless of its type or origin, and could provide data from which at least some of the collected organic material could be identified. The chromatographic fingerprints obtained by this method would very probably be unequivocal concerning the presence of biochemicals but somewhat equivocal with respect to whether they represented a prebiotic stage of development or arose from either living or dead organisms. The current status of the experiment is somewhere between functional-feasibility breadboard and flight-sized breadboard. For a flight-sized instrument, a current estimate of the weight is about 7 pounds; the volume, 200 cubic inches (without sample acquisition); the power requirement (exclusive of environment control) is 4.5 watts. Data are taken for a 40-minute period and require special handling in storage and transmission. Orientation of the instrument on the surface of Mars is not a crucial consideration. The instrument must be protected against the Martian night. (It will survive within the temperature range of -50° to ±135° C.) In order to produce a final instrument the current budget would need to be increased from $206,000 to about $425,000. Correspondingly, the current staff of four scientists and engineers and two technicians would need to be increased by the addition of four engineers and five technicians. With these additions at an early date, the experiment would appear to be capable of meeting the schedules for the 1966 mission. However, considerable effort is required to develop a suitable sample collection and preparation device.

Gulliver

The experimenters for Gulliver are Dr. Gilbert Levin of Resources Research, Inc. and Dr. Norman Horowitz of the California Institute of Technology. The experiment is designed to measure the growth of bacteria by monitoring the formation of radioactive carbon dioxide produced by the metabolism of radioactive substances. If the experiment were to function as planned, it would indicate the presence of a biota that could utilize the added sources of carbon, nitrogen, and energy for growth. If the production of carbon dioxide were exponential, as is characteristic of binary fission, growth would be indicated. If the production were not exponential, it would not be clear if the carbon dioxide release would be a result of cell-free enzymatic degradation metabolism in the absence of growth, or chemical degradation of the radioactive substrate. The success of the experiment depends, of course, on being able to supply the appropriate environment for growth. The use of controls is also difficult because identical samples are not provided to both the test and control chambers. Sample acquisition, in general, may be a problem although Gulliver does include an acquisition device. (One of a few surveyed experiments that does.) At the present time, the experiment can be considered in the status of an advanced flight-sized breadboard model. (It was field tested in a flawless manner for the survey team.) Based on current estimates and models, the weight is between 7 and 12 pounds; the volume, between 300 and 600 cubic inches; the power requirement is 3 watts average and 5 watts peak without heater (an additional 2-1/2 watts is estimated for a heater). At least two readings will be required although more would be desired. Gulliver will require protection from the Martian night as indicated in the power requirements and, should nuclear power be used on board the spacecraft, shielding would also be required. The instrument is not sensitive to spacecraft orientation on the Martian surface. Insofar as instrument problems are concerned, Gulliver should be capable of meeting the schedules for a 1966 mission if between $250,000 and $350,000 is applied to flight prototype development.

(This development is now subcontracted to American Machine and Foundry, Alexandria, Virginia.) In fact, this experiment was the farthest along, in terms of hardware development, of all those surveyed. In addition, approximately another $50,000 might be required for laboratory work.

"J" Band

The experimenter for the "J" Band is Dr. R. E. Kay of the Aeronutronic Division of the Ford Motor Company. The experiment is intended to detect the shift of the absorption band of a dye molecule (thiocarbocyanine) to one or two new wavelengths upon interaction of the dye with certain organic macromolecules such as proteins and/or nucleic acids. If the experiment were to function as planned, the existence of either or both proteins and nucleic acids on Mars could be established. Indication of either would be highly indicative of the presence of life. It should be noted, however, that high salt content in the sample can obviate the results. This effect of salt can be vitiated, according to laboratory tests, by increases in temperature, use of 10-percent alcohol solutions, or by dialyzing the sample prior to analysis. At the present time, the experiment has been reasonably well demonstrated in the laboratory. Many proteins and nucleic acids have been tested with and without interfering materials. No flight-type hardware has been set up. The hardware proposal is as yet conceptual. It is estimated, however, that an appropriate instrument might weigh 5 pounds, use 3 watts of power, and have a lifetime of several weeks. Six readings at three different temperatures will be required. Primary protection requirements would be against the Martian night. The instrument properties just noted do not include sample acquisition. Since the sensitivity threshold of the measurement is about 1 microgram of active protein or nucleic acid, collection and processing of relatively large samples of material is a problem which remains to be solved. As far as the chemistry is concerned, the experiment is well along and could be ready for a 1966 mission with the application of about $100,000. For instrument development, another $400,000 would be required for the period of about 1 year. No positive steps in the direction of instrument development have been taken to date raising real doubt that the experiment could indeed be ready for 1966.

Mass Spectrometer

A life-detection experiment based on mass spectrometry is being developed under NASA Grant NSG 211-62 which is entitled "The Detection and Identification of Organic Matter by Mass Spectrometry." The experimenter is Dr. Klaus Biemann, Professor of Chemistry, Massachusetts Institute of Technology. The experiment is intended to identify organic molecules by interpretation of a mass spectrogram. If this experiment were to function as planned, it would indicate the existence or nonexistence on Mars of organic compounds as they are known on earth. By its nature the experiment could not determine if these compounds were part of life that had existed, that does exist, or that is in the process of evolving. For example, the presence of organic compounds arising from ultraviolet radiation of gaseous mixtures would be detected by the experiment. While the detection of such compounds does not indicate the existence of life, their presence on Mars would in itself be significant. At the present time, the experiment is in the conceptual state. In particular, standard mass spectrometers are being used to examine synthetic mixtures of organic compounds. Complete groups of compounds obtained by breaking down an entire living organism have not as yet been examined. The complex spectrograms obtained from such mixture may prove difficult to analyze. Based on current estimates, a flight instrument (exclusive of sample collection equipment) would weigh about 15 pounds and would occupy about 400 cubic inches. A meaningful spectrogram may involve the taking of 250 pieces of information. The instrument itself would not require any special protection from the space environment other than that normally required for electronics. Orientation relative to the Martian surface is not important other than for the purposes of sample acquisition. This latter problem, sample acquisition, has not been considered in detail and this lack seems to be one of the most serious problems in the status of the experiment. As estimated by the experimenter, about $350,000 and two additional men would be required to meet the 1966 mission schedules. It was noted, however, that at least 6 months would be required for the acquisition of a miniaturized spectrometer. For this reason and because of the sample acquisition problem and the relatively high weight, it would appear that a 1969 launch date might be more compatible with the experiment time table.

Multivator

For the Multivator instrument, the experimenter is Dr. Joshua Lederberg, Department of Genetics, Medical School, Stanford University. He is being assisted in the engineering aspects of the device by Dr. Elliot Levinthal and by Messrs. Lee Hundley and

J. Arnold. The Multivator can be characterized as a miniature biochemical laboratory that can accommodate a variety of biochemical experiments. It can be described as a group of cells or tubes in which samples are introduced and combined with appropriate reagents or biological materials. The resulting action of the sample material is then detected with a photoelectric device. To date, the Multivator has been considered primarily for use in the detection of the action of phosphatase on phosphate containing chemicals which become fluorescent following removal of the phosphate group. It has also been considered for use in the detection of the action of biologically important macromolecules as they evidence their presence by chemicophysical changes that may be detected by fluorescence, turbidimetry, nephelometry, absorption spectra, or absorption spectral shifts of a test substrate. If the device were to function as planned, a positive result would indicate the existence on Mars of the enzyme phosphatase. Detection of phosphatase would not permit a distinction between the past, present, or future existence of life. As a device, the Multivator is being developed into a flight-sized breadboard. In the opinion of the experimenter it is nearly ready for transfer to a commercial concern for flight hardware development and flight qualification testing. As far as experiments for use with the device are concerned, the existence of a stable organic reagent for use in the phosphatase experiment remains to be demonstrated, although progress is being made in this area. From the point of view of this experiment, then, the Multivator is still in part in the conceptual stage. Other experiments for inclusion in this device are yet to be considered. With sample collection included, current estimates indicate the weight at about 3 pounds, the volume at about 90 cubic inches, and power requirements at 1 watt average and 5 watts maximum. Each of fifteen chambers would be read at about 15-minute intervals for a period of at least 1 hour. Power requirements are largely dictated by the survival problem for the Martian night. An estimate of the funding for the biochemical studies and organic chemical preparations has been given in a proposal to NASA Headquarters by Dr. Lederberg. It is estimated that the development remaining for the instrument itself will amount to about $300,000. Multivator could be ready as a device for 1966 but the experiments it would house will need a great deal more effort if they are to be ready at that time.

Minivator

The Minivator is an instrument very similar in nearly all respects to the Multivator discussed in the previous section. The experimenter is Mr. Jerry L. Stuart of the Jet Propulsion Laboratory. One particularly attractive feature of the Minivator is its sample collection device which is one of the most advanced of such systems covered by the team. The collection device, which is driven by a gas turbine, stirs up and collects dust particles. Separation of large particles is accomplished by centrifugal action. The Minivator is in an advanced state of engineering and as an instrument could be ready for the 1966 mission with additional support of about four men and $220,000. Evolution of appropriate experiments for the device would be difficult to complete in time without an accelerated program with about $500,000. Some attention should also be given to the combination of this effort and that for the Multivator. In the remaining sections of this report, it will be assumed that the effort on these two devices will be merged.

Optical Rotation

The experimenters for Optical Rotation are Dr. Ira Blei and Mr. Sol Nelson of Melpar, Inc. The experiment is designed to measure the optical rotation of plane-polarized monochromatic light (254 millimicrons) when it is passed through a solution prepared from a soil sample. If the experiment were to proceed as planned, the presence of optically active compounds on Mars would be indicated. These compounds would presumably arise via an asymmetric synthesis catalyzed by a living organism. There is the possibility that combinations and concentrations of asymmetric materials could exist in the sample that would result in a net zero rotation. At the present time, the instrument exists as a laboratory model. Current estimates for a flight-sized instrument indicate the weight at 5.2 pounds, the volume at 130 cubic inches, and the power at 1.1 watts (exclusive of protection). The device requires that only one reading be made after a period (from start of experiment) of 415 seconds. The instrument has no particular orientation requirement and needs protection from the Martian night. Based on current proposals, the cost of development of a flight instrument would be $274,652, primarily for engineering and engineering support. The Optical Rotation experiment would appear to be an adequate one, but at the present time there is no sample collecting device or a sample preparation technique for use in conjunction with this experiment. Both of these are an absolute must for the success of the experiment on Mars. The sensitivity of the technique is also questionable. The probable low densities of Martian life suggest that either sample concentration will be required or that relatively large samples will have to be processed. For these reasons this experiment does not appear to be a good candidate for a 1966 mission, but may be one for a 1969 mission.

Wolf Trap

The experimenters for Wolf Trap are Dr. Wolf Vishniac and Dr. C. R. Weston of the Department of Biology, University of Rochester. The experiment is designed to measure bacterial growth in appropriate media by detection of changes in pH and in turbidity. If the experiment were to function as planned, it would indicate the presence on Mars of physiological types capable of utilizing supplied sources of carbon, nitrogen, and energy for growth (as measured by turbidity) and/or physiological types capable of changing the concentration of hydrogen ion at the expense of nutrients in the supplied media. If, however, the sample introduced in the device contained large amounts of colloidal particles, the background noise might obscure any changes in turbidity. Furthermore, the presence of hydrophilic substance, which might swell, could produce light scattering without growth. Similarly, if the sample contained highly buffered soil, changes in pH might be prevented, while on the other side, the slow release of relatively insoluble acidic or basic substance could give a change in pH without growth. At the present time, the Wolf Trap is between the conceptual and feasibility breadboard status. Negotiations are in progress (with Ball Brothers) for a contract to construct a flight-sized model. Based on current estimates the flight instrument would have a weight between 2 and 5 pounds (one or five chambers, respectively), a volume between 125 and 400 cubic inches, and a power requirement of about 1 watt. For each chamber, five channels will be read about every 15 minutes until a minimum of about 40 readings has been obtained. The instrument would have to be oriented within about 60° of the local vertical. Protection requirements have not as yet been evaluated. In summary, the sensitivity of this experiment seems to be fairly low in that a high density of organisms is required. The device includes a sampler, but not adequate sample preparation and concentration to give a sufficiently high number of organisms per tube. The device also has a very high data transmission requirement which would appear to be beyond the capability of a 1966 vehicle. It does not appear likely that this experiment could be ready for 1966 but may be a candidate for 1969.

Other Experiments

Several other experiments were covered by the survey but in somewhat lesser detail. For example, work has just begun at Princeton University under Dr. Robert D. Allen on a microscopic system to measure dichroism, optical rotation, and phase retardations. Due to the early stage of the effort, the device cannot be considered for the 1966 mission. It was not possible, in fact, to make a quantitative survey of this experiment.

Another experiment was the ultraviolet spectrophotometer under study at Malpar, Inc. This device would be used to look at peptide bonds at 1800 Å. This experiment may be limited by the unavailability of a solvent that will not absorb strongly at this wavelength. Interference from other materials is also unevaluated.

Some preliminary work has been done at Resources Research in an attempt to convert Gulliver to a device that can detect the presence of a photosynthetic organism. Presumably the detection would be accomplished by observation of the differences in generation of carbon dioxide in the presence or absence of light. This modified device would appear to be of interest but it is in too early a stage for the 1966 mission.

An experiment which is designed to detect microorganisms by determining the presence of Adenosine Tri Phosphate (ATP) is also being considered at Resources Research. This experiment may not require a landing vehicle since, at least potentially, it can be used on a probe if a high-volume sampling of the atmosphere during descent can be achieved. Demonstration of the experiment has been achieved in the laboratory on earth organisms. However, no work has been done toward an exobiological experiment and there is currently no program to do this. More detailed information on this experiment is given in appendix B. This information was voluntarily furnished by Dr. Gilbert Levin of Resources Research to personnel of the Exobiology Division at Ames Research Center.

An automatic paper chromatograph for detection of organics in soil is being tested for feasibility by Dr. Wolf Vishniac at the University of Rochester. Dr. Vishniac does not consider this device as a candidate for the 1966 mission. There are, of course, many similarities between this device and the gas chromatograph discussed previously.

A final device considered was the Vidicon Microscope. It has been estimated that the transmission of an image from a microscope on Mars would take 10^5 bits for a poor picture and 10^7 bits for a good picture. When this very large data requirement and the problems of specimen preparation and slide searching were considered, no further attention was given to this device.

SURVEY OF VEHICLE SYSTEMS

This section is broken down into subsections describing various vehicle systems composed of four basic launch systems. The launch systems considered are Atlas-Agena, Atlas-Centaur, Saturn I, and Saturn I-B. The payload capability (i.e., weight to Mars) of each booster system is taken to be that consistent with present state-of-the-art estimates. In particular, the potential increase in booster capability due to fluorination of the Atlas stage is only briefly considered. A study program of the feasibility of LOX fluorination has only recently been initiated at the Lewis Research Center so that any benefits which may be forthcoming from this procedure must be considered only speculative at the present time.

The mission profiles and vehicle systems considered are those systems derived from previous studies, either industry or NASA Center studies. The intent here is to present briefly some of the salient features of typical mission modes associated with each booster system so that the compatibility of life-detection experiment requirements with a particular vehicle system capability can be easily assessed. It might be noted at this point that all entry vehicle and landing system weights are based on the Schilling model atmosphere. Effects of deviations from this assumed atmosphere will be discussed later.

Atlas-Agena System

The Atlas-Agena booster combination is capable of putting approximately 450 pounds on the way to Mars. If consideration is given to improved versions of the Agena system, the injection payload increases to approximately 550-600 pounds. If still further consideration is given to fluorination of the Atlas booster stage, the payload may increase to a probable maximum of about 750-800 pounds. Mission studies to date indicate that injected payloads of this magnitude are not sufficient to yield a significant and reliable capability to place a payload on the surface of Mars. Hence, the Atlas-Agena systems will probably continue to be limited to flyby missions in the future insofar as the planet Mars is concerned.

Atlas-Centaur Systems

It has been difficult to obtain definitive information on the performance capability, operational status, and scheduling of the Atlas-Centaur vehicle. Based on discussions with various members of the Lewis Research Center and a telephone conversation with Mr. Vince L. Johnson, Head, Centaur Program, NASA Headquarters, the following conclusions have been drawn. The Atlas-Centaur will be capable of placing approximately 1300 pounds into a transfer trajectory to Mars. The maximum axial loads during launch will probably not exceed 6 g. Both axial and lateral vibrational loads will probably be less than 5 g. It will be available for two launches to Mars during the late 1966 window, although no specific vehicles have been scheduled to that point.

Two basic spacecraft systems sized for the Atlas-Centaur launch systems are briefly summarized below. The first system resulted from studies made by personnel at the Jet Propulsion Laboratory and will be subsequently referred to as the "flyby bus plus capsule" system. The second system was evolved by members of the staff at Goddard Space Flight Center and will be referred to as the "bus plus capsules" system.

Flyby bus plus capsule system.- The majority of the spacecraft mission profile of this system is identical with that of Mariner C. The profile is based on a capsule release near the planet and a relay link communication system via the bus as it flys by the planet. An alternative capsule, in which a direct communication link is employed, is also considered. The direct and relay communication links require different capsule weights so that the total weight to Mars for each system is 1204 pounds and 1254 pounds, respectively. These weights are within the expected capability of the launch system.

The bus part of the spacecraft is functionally identical with the Mariner C system but modified to include the addition of the landing capsule with its resulting support requirements. Thus, whereas the Mariner C spacecraft weighs 596 pounds, the present spacecraft bus weighs 807 pounds, of which about 50 pounds is allotted for instruments to make planetary and interplanetary measurements including scan equipment for the planetary measurements. These instruments would probably not be volume limited.

Both the direct and relay communication link capsules are 48 inches in diameter and weigh 397 and 447 pounds, respectively. The capsules will contain an ejectable entry subsystem including heat shield and structure, a retardation system, landing impact and orientation equipment, temperature control equipment, power storage and conversion equipment, a one-way communication system for scientific and engineering telemetry, separation equipment, on-board programming and sequencing elements, and instrumentation, sampling, data handling, and storage equipment. A component weight breakdown, including capsule subsystem weights along with other pertinent information for this and subsequent spacecraft systems considered, can be found in table III.

The capsule guidance and control system weight is composed of the post-separation attitude stabilization system and the propulsion system and support weights. Since the orientation of the landed capsule relative to the flyby bus is critical for the relay system, the propulsion requirements are greater than for the direct system. This is reflected in the greater guidance and control weight shown for the relay system in table III. It should be noted that this does not affect the capsule entry weight for either system, since the guidance and control system is ejected prior to entry.

The structures and heat-shield weights include ablation and insulation weights, aft covers, thermal control equipment, and internal structure.

The parachute system and the landing system comprise the terminal deceleration weights. The parachute system includes all chutes, reefing and cutting gear, stowage bags, sensors, deployment equipment, and release systems. The landing system includes all hardware required for impact attenuation on the surface, erection of the payload, and orientation as necessary.

The payload weight available for all experiments in both systems is 30 pounds and does not include the data storage system. The latter system amounts to about 4 pounds and has been included in the communication system weight. The volume available for the experiments cannot be fixed absolutely but is estimated to be about 2-3 cubic feet for both systems.

The maximum entry deceleration is expected to be about 150-200 earth g. The landing or impact loading is not expected to exceed this level. In view of the fact that the maximum launch loads were estimated to be only about 6 g, the maximum g loading constraint for the experiments is about 200 g.

The power for both capsule communication systems is provided by batteries so that the power system weights shown in table III are due solely to batteries. The total mission lifetime due to power limitations varies from 30 hours for the direct link system to 40 hours for the relay mode.

The spacecraft bus design is compatible with the use of the 85-foot receiving antennas operating at S-Band. Use of the 210-foot antenna at Goldstone will be required for capsule operation in a direct capsule-earth mode. The 210-foot dish will be desirable but not required for the relay mode. The capsule transmitter used in the direct link delivers 36 watts of radiated power whereas the transmitter in the relay link delivers 45 watts of radiated power. The data rate for both communications systems is 6 bits per second and earth acquisition time is 200 seconds. As shown in table III, both systems are comparable in regard to communication system weight.

A further constraint on the experiment package is that due to sterilization. The present plan being considered at the Jet Propulsion Laboratory is heat sterilization of the entire entry capsule. This will require a temperature capability of 300° F for 24 hours for each experiment and supporting equipment.

Bus plus capsules system.- In this spacecraft system, the bus as well as the capsule enters the Martian atmosphere. However, after ejection of the capsules, the bus is designed to be destroyed by entry heating. This system represents a "minimum weight" approach since the total injection weight to Mars is only 980 pounds. Two entry capsules are included in this system weight. For this reason, this system is considered to have a higher degree of reliability than the "flyby bus plus capsule" system. It appears possible, also, to add a third entry capsule thereby further increasing the reliability factor.

The spacecraft bus has a nominal diameter of 65 inches and is capable of carrying up to 20 pounds of experiments. Such experiments do not appear to be volume limited and they can be designed to measure the physical parameters of the planetary exospheres from their outer limits down to the altitude at which the bus burns up on entry.

Each entry capsule is approximately 39 inches in diameter and weighs 176 pounds. It is comprised of the heat shield including its supporting structure, insulation, afterbody, and deployment power and an instrumentation section. After the capsule has entered the atmosphere, the parachute is deployed at the proper altitude and the heat shield is dropped along with other structure leaving only the instrumentation section as the landing vehicle. Impact survival is obtained through the use of an impact mitigator located on the side of the instrumentation section facing the planet during parachute descent. The instrumentation section contains the active and passive components necessary for planetary measurements. It is cylindrical in shape and has a diameter of 10 inches and a length of 20 inches. It contains 3 modular units: (1) batteries, (2) electronics for data acquisition, and (3) transmitter. The experiment sensor package bolts externally to the parachute side of the cylinder, that is, opposite the impact mitigator.

The spacecraft is spin stabilized. The propulsion requirements for guidance applies to the complete spacecraft so that the guidance and control weight is assigned to the bus and none is assigned to the capsule in table III.

Of the 84 pounds listed for structures and heat shield in table II, 8 pounds represent electronic support structure. Ablation, insulation, structure, and afterbody weights account for the remaining 76 pounds.

The parachute system weighs 20 pounds. This weight and the 7 pounds necessary for the shock mitigator on the instrument probe make up the total terminal deceleration system weight.

Each capsule has an experiment payload capability of 15 pounds so that 30 pounds is available with the two-capsule spacecraft system. As mentioned earlier, the system is capable of transporting three entry capsules to Mars and still be within the payload capability of the Atlas-Centaur launch system. Thus, 45 pounds may be available for experiments. The experiment payload volume, however, represents a serious limitation, since it is estimated to be only about 1 cubic foot per capsule.

The maximum capsule deceleration during entry is about 90 earth g. On impact, however, the instrumentation probe can experience a maximum loading of approximately 140 earth g.

Approximately 800 watt-hours of energy are required to accomplish the capsule mission. This requirement can be fulfilled by the use of batteries - specifically, 23 pounds of silver/zinc cells. The total lifetime due to power limitations is 48 hours.

The over-all spacecraft system presupposes the use of telemetry band at 2300 MC and the DSIF. The 210-foot receiving reflectors are also required. The entry capsule and the bus are each capable of furnishing 5 watts of power to the experiments when information is being transmitted. Experiment output is converted to digital form using 7-bit word presented at a 1-bit per second rate.

The planned sterilization procedure for this spacecraft system includes sterilizing both bus and capsules. It also includes the internal sterilization of all parts, components, and materials by baking at 260° F for 26 hours. Thus, the temperature constraints on the experiments for this system are similar to those of the flyby bus plus capsule system.

Saturn Systems

The first phase of the NASA interplanetary program consists of vehicles in the Mariner class - that is, vehicles sized for either the Atlas-Agena or the Atlas-Centaur launch systems. The follow-on phase has been termed Voyager - that is, vehicles sized for the Saturn booster. Although the 1966-67 Mars mission is considered in the Mariner class, some results of recent Voyager mission studies are discussed below to point up the potentially large payload capabilities of systems sized for the Saturn I and I-B boosters which might be available should the presently conceived Atlas-Centaur system prove deficient or should it be delayed to the 1969 launch window. For example, typical vehicle weights which can be injected into an Earth-Mars transfer trajectory using Saturn I and I-B launch systems are shown in table III and are 3200 and 6000 pounds, respectively.[1] These weights represent approximately a two- to five-fold increase in injected payload capability compared to the Atlas-Centaur vehicle. As discussed later, this can be translated into a one to two order of magnitude increase in payload landable on Mars' surface. Based on industry studies, it appears possible to have such Saturn-class payloads available for launch at the occurrence of the January 1967 launch window. However, there may be a question on the availability of a Saturn booster for this Mars opportunity due to other program commitments.

The weight breakdowns and other information shown in table III for the Saturn launch systems were obtained from mission studies made by industry for a January 1967 launch date. For later launch dates, such as the 1969 or 1971 window opportunities, the numbers shown in the table will change but the comparisons and general trends discussed below will remain essentially the same. The studies referred to above are conceptual so that the numbers shown in the table are preliminary and approximate. They merely represent estimates of what appears to be a feasible capability of a vehicle system which comprises a bus and lander in one case and an orbiter and lander in the other case. For purposes of this brief discussion, only certain mission capabilities of the landers are considered.

It will be noted from table III that, in general, a greater percentage of the vehicle system weight can be allotted to the lander with increasing vehicle system weight (i.e., booster capability). Of greater importance, however, is the fact that the percentage of the system weight to Mars available for experiment payload, that is, payload fraction, increases substantially for the heavier systems. This is depicted graphically in figure 1. It can be seen, for example,

[1]The complete Saturn launch system is presumed to have a third stage for injection into the transfer trajectory.

that the payload fraction increases from about 3 percent of the injected weight in the case of Atlas-Centaur systems to over 30 percent for the Saturn I-B system. It is realized, of course, that not all of the systems and/or mission profiles were derived from the same ground rules. Nevertheless, the trend indicated in figure 1 is still valid since, in each case, the system represents at least a quasi-optimization of payload weight.

The entry capsules of all the systems considered had essentially the same shape as the NERV-Discoverer capsule. Therefore, only the weight and size of the vehicle affected the heat-shield considerations. The weight penalty for heat shield and structures comprises about 50 percent of the entry capsule weight for the lower weight Centaur systems. This percentage is less than 20 percent in the case of the heavier Saturn systems. One implication of this result is that minimum weight systems suffer in payload capability because of the heat shield and structure requirements.

One of the constraints employed in the study of the Saturn-sized vehicles was that the impact loading was to be no greater than the maximum entry deceleration. Since this deceleration was found to be 90 g, this is the value used in table III to represent the loading constraint on the experiments for this system. It will be noted that it is actually less than for the other systems.

The communication and power systems weights for the Saturn system landers represent the largest increase in weight requirements. However, both the communication and power systems capabilities have also increased substantially. Notice, for example, that the data transmission rates are higher by three orders of magnitude and the lifetime has increased by nearly two orders of magnitude. The use of a 250-foot dish was assumed in this study. The conclusions are essentially the same for a 210-foot dish compatibility.

The sterilization requirements were assumed to be the same as those used at the Jet Propulsion Laboratory so that the temperature-time constraints are the same as those for the flyby bus plus capsule system.

DISCUSSION

As is apparent in the descriptions contained in some of the foregoing sections, the life-detection experiments surveyed fall into two general categories. One of these is based on organic analysis, that is, the detection of organic compounds. The second is biological, that is, the detection of growth and/or metabolism of some indigenous living system. Neither of these techniques by itself is guaranteed of success in the detection of life. The major shortcoming of the growth or metabolic experiments is that their success is totally dependent on a successful choice of media. All proposed media are aqueous and the proposed experiments by necessity will be carried out at high levels of water activity. This choice may be a very large gamble for Mars in that any organism introduced to the medium will have had an evolution that has been most likely in the opposite direction, since liquid water on Mars is at best an unlikely event and may well be impossible. For example, possible candidates for life on Mars are halophilic organisms. Some halophiles not only fail to grow but are lysed when placed in media containing low concentrations of "salt." Primarily for these reasons, the detection of organic compounds on Mars is probably a more reliable preliminary approach to extraterrestrial life studies. However, such detection is not necessarily indicative of the presence of life, since it has now been shown that organic compounds can be synthesized abiogenically under primitive conditions. The presence of such compounds nevertheless would be of great scientific importance as well as being a possible indication of life.

In terms of the specific objectives of the present study, the results obtained by the team indicate that there are three experiments which have a reasonable chance of being ready in time for the 1966 Mars-Mariner mission. These are the Gas Chromatograph, Gulliver, and Multivator (or Minivator). At present, however, Multivator has no complete experiment. The Gas Chromatograph and Gulliver have problems of sample collection, preparation, and concentration, although these problems may be somewhat less for the Gas Chromatograph than for Gulliver from the standpoint of sample concentration. The increased support required for any one of these experiments, to meet the 1966 schedule, would amount to between $200,000 and $425,000 (see table I).

While each experiment has its own problems, the most serious problems that exist in the selection of a life-detection experiment for the 1966 mission appear to be of a universal nature, common to all experiments. Among the most important of these is the current status of sampling systems. To date, no adequate sampling device, sample concentration mechanism, and sample preparation system has been devised. In view of the probable low concentration of life on Mars, the development of adequate sampling systems is a difficult task. For example, the Martian soil (if the term is applicable) will probably contain fewer than 10^5 bacteria per cubic centimeter found in earth desert soil. The few attempts that have been made to incorporate sampling systems into life detection devices are considered inadequate and preliminary. The problem of sampling, then, at this stage is probably more fundamental and important to life detection than the life detection device itself. In fact, the absence of suitable sample collecting and concentrating devices at this time may actually prevent the inclusion of a life-detection device for the 1966 Mariner. It would be helpful, although perhaps not feasible, if a single sample collection device could be devised which could obtain and prepare samples for more than one life-detection experiment. It is one recommendation of the survey team, then, that the development of devices for sample collection, concentration, and preparation be given prompt consideration.

In most respects, the problems introduced by the need for sterilization are also common to all experiments. These problems affect primarily the electronic components of the device and all experiments have these components. Since the problems of sterilization are being thoroughly dealt with elsewhere, they have not been treated in any detail in the present report. This exclusion does not indicate any feeling that the sterilization problem is not a serious one, however, and care was taken to gather as much information as possible on the particular sterilization problems associated with each experiment. This collected material is contained in appendix B.

Another problem exists because a definition of the experiment vehicle interface is lacking. At this time, all experiments which have reached some stage of hardware development are hampered as far as actual prototype development is concerned since there has been no experiment-vehicle interface on which to base prototype development. The 1966 Mariner mission and vehicle must be defined before such prototype development can proceed. It appears pointless to strive for experiment hardware development without knowledge of the limitations imposed by the transport vehicle. It is another recommendation of the team, therefore, that every effort be made to define the vehicle-experiment interfaces and that this information be disseminated to all experimenters.

In a more general sense, it appeared during the present survey that there was a lack of communication between the various experimenters involved in the life-detection program. For this reason, it may be appropriate to consider the institution of periodic meetings of an informal nature during which the several experimenters could converse on mutual problems and where they could be advised of the problems associated with the constraints imposed by the transport vehicles.

Probably the most serious drawback to the Mariner 1966 mission for the detection of life on Mars is the marginal capability of the Centaur vehicle systems. Although the Centaur systems considered earlier appear to have the payload and telemetry requirement capabilities to place the Gulliver, Gas Chromatograph, and Multivator experiments on Mars (see tables II and III), there are other considerations which make the use of these systems highly doubtful. To be specific, existing knowledge of the environment of Mars indicates that if life does exist, it would be limited to certain regions of Mars which can be reasonably well defined. For example, life on Mars in any appreciable concentration is almost certainly limited to latitudes of some 30° or 40° and even in this belt it may be restricted to the dark areas which constitute about one-third of this region. The area of interest is then about one-fifth of the Martian surface. With the Centaur system, however, the guidance and control capabilities are limited and the landing site cannot be controlled. The vehicle may very well land in some location in which one would not even remotely expect to find life, such as the polar caps. It appears then that there is a reasonable chance of missing a suitable location for a life-detection experiment.

Another very serious problem is the uncertainty in the atmosphere of Mars. The vehicle studies previously discussed were all based on the Schilling model atmospheres. Recent interpretation of observed data by Dr. L. Kaplan of the Jet Propulsion Laboratory indicates substantially lower surface pressures (about 15 millibars) compared to the mean Schilling model value (about 85 millibars), and a much higher CO_2 content. If the surface pressures are indeed lower, then the 1966 Mariner vehicle studies will have to be re-evaluated and it would seem that, at best, a very large uncertainty exists in the assumption that a soft landing with a usable payload can be assured. It should be noted, also, that at a pressure of 15 millibars, water boils at 56° F and freezes at 32° F so that there is only a 24° F range for liquid water to exist.

Since the difficulties associated with lack of landing site control and with atmospheric uncertainties will probably not be resolved for the 1966 mission, it may be desirable to delay the life-detection experiments to a date compatible with a Voyager-type vehicle. Such a delay, of course, is not attractive. In view of the significance of a positive answer, it may very well be worth a considerable gamble to include any available life-detection experiment in the 1966 mission even though the uncertainties are so extensive.

In summary, it would seem advisable, if a soft lander is indeed feasible for the 1966 Mariner, to include a life detection device which is not dependent on growth or metabolism, but rather a device designed for analysis such as the Gas Chromatograph or possibly the Mass Spectrometer. Both of these experiments are capable of a fairly detailed analysis of the surface composition, particularly in regard to organic content. If possible, other determinations such as temperature and atmospheric composition should be made at the same time. Particularly important are temperature measurements, giving some spatial resolution across the surface of the planet. With this type of information, later landers of the Voyager type with larger payload capabilities can incorporate those experiments such as Gulliver, which give us much more detailed information concerning life. If, on the other hand, the atmosphere of Mars is such that a soft lander for the 1966 mission is not feasible, then it does not seem likely that a life-detection experiment can be included at all and a strong emphasis should be placed on the definition of the atmosphere (thermodynamic structure) as the primary vehicle experiment so that design of a lander for later Voyager-type missions could be insured.

CONCLUDING REMARKS

As a result of the survey that has been made of life-detection experiments, it appears that only three have a reasonable chance of meeting the schedules imposed by the 1966 Mars-Mariner mission. One of these three is the Multivator, for which there is no complete experiment. The other two are the Gas Chromatograph and Gulliver, which have either sample acquisition or preparation problems (Gas Chromatograph) or sample concentration problems (Gulliver).

The most serious problems encountered in the present survey are of a universal nature, common to virtually all experiments. Some of these can be corrected by appropriate action; others cannot. For example, adequate sample collection, concentration, and preparation devices have not been devised. In view of the probable low concentration of life in the Martian soil, this omission is serious and it is recommended that the development of appropriate devices be given prompt attention. It is also recommended that clear definitions of experiment-vehicle interfaces be evolved and supplied to all experimenters. Lack of these definitions is currently hampering instrument prototype development.

Problems for which corrective action is probably not possible before the 1966 mission result from the inability to control the landing site and from the uncertainties in the Martian atmosphere. Both of these problems have serious ramifications in terms of the probable success of a life-detection experiment. These ramifications are so serious that the inclusion of a life-detection experiment on the 1966 Mariner may be an exceedingly poor risk. It may, for example, be more appropriate to delay such experiments for a Voyager vehicle. If, in the end, the decision is to include a life-detection experiment on

Mariner, it is recommended that it be one not dependent on growth or metabolism for success. Such experiments require the added uncertainty that a suitable ecology must be provided for unknown life forms.

APPENDIX A - DOCUMENTATION

COPY COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington 25, D. C.

In reply refer to: SB May 22, 1963

MEMORANDUM TO: Director, Ames Research Center

FROM : Director, Office of Space Sciences

SUBJECT : Life Detection Experiments for Mars Mariner 1966 Mission

Your attention is invited to the attached memorandum from Dr. Orr E. Reynolds.

It is requested that the Ames Research Center prepare the status report as outlined by Dr. Reynolds, with a final report due in the Headquarters not later than 15 August 1963.

Your early response to this request will be appreciated.

/s/ E. M. Cortright

Homer E. Newell, Director
Office of Space Sciences

Attachment:
Memorandum from SB

BBH:jj

COPY COPY

United States Government
MEMORANDUM

To: : S/Dr. Homer E. Newell Date: 17 May 1963
(FQ:jmh)

From : SB/Dr. Orr E. Reynolds

Subject: Status and Recommendations for Life Detection Experiments to be Considered for the Mars Mariner 1966 Mission

It is necessary for the Biosciences Subcommittee to arrive at a decision concerning one or more exobiology experiments to be included on the first Mars landing capsule. In order to do this, the subcommittee must be brought up-to-date on the status of those experiments which are presently in varying degrees of study and development.

Although only 8 or 10 experiments are involved at the present time, the overall job is quite complex and is far beyond the time and talent available in my own staff.

It is suggested, therefore, that this job be assigned to an organization with biological and engineering competence as well as one free of bias towards any particular approach or scientific personality. In spite of the thus far limited manpower in exobiology at Ames, this group together with the consultive services available in the Bay area (particularly at Berkeley(and the excellent Instrumentation Division at Ames, places this center in a unique position with respect to the aforementioned criteria. The responsibility and mission of the Ames Research Center with respect to NASA's overall organization, indicates that this problem falls within the province of the Center's mission and capability.

It is therefore requested that the Ames Research Center be asked to determine the status of each of the proposed "life detection" experiments, to determine what must be done to make them ready for the 1966 mission, to determine which experiments cannot satisfactorily meet the schedule for the first mission under any circumstances, and to submit finalized recommendations to my office by 15 August 1963.

An early response from the Center's Director is needed together with the proposed procedure for handling the assignment. The Jet Propulsion Laboratory, Goddard Space Flight Center, and NASA Headquarters are prepared to provide any information or assistance required for expediting this study.

/s/ Orr E. Reynolds

Orr E. Reynolds, Director
Bioscience Programs
Office of Space Sciences

COPY COPY

May 29, 1963

From Ames
To NASA Headquarters - Attention: Dr. Homer E. Newell, Code: S

Subject: Life Detection Experiments for Mars Mariner 1966 Mission

Reference: NASA Hq. let., May 22, 1963, Dr. Homer E. Newell, Ref. SB

1. Ames Research Center is pleased to comply with the request of your letter of May 22, 1963. To this end a Life Detection Experiments Team is being established at the Center under the chairmanship of Mr. C. A. Syvertson, Chief of the Mission Analysis Division, and with appropriate members from the life science, physical science, and engineering elements of the staff.

2. This team is charged with carrying out all evaluations and independent studies required to prepare the status report on the subject experiments and the final recommendations for your office by August 15, 1963. You will be regularly advised of the team's activities when it is fully organized and operating, and we will welcome additional information and assistance as required from your office, the Jet Propulsion Laboratory, and Goddard Space Flight Center.

/s/ Smith J. DeFrance

Smith J. DeFrance
Director

AJE:jd

COPY COPY

NASA - Ames

Moffett Field, California
May 31, 1963

MEMORANDUM for Division Chiefs and Branch Chiefs

Subject: Formation of a Life Detection Experiments Team at Ames Research Center

1. This Center has been requested by the Office of Space Sciences to prepare a status report and submit final recommendations on life detection experiments for the Mars Mariner 1966 Mission. Pursuant to satisfying this request, there is established, effective immediately, a Life Detection Experiments Team at Ames Research Center. This team will operate as an ad hoc element of the Mission Analysis Division, and it will consist of the following members:

Mr. C. A. Syvertson, Chairman

Science	Engineering
Dr. Richard Young, Vice Chairman	Mr. Raymond C. Savin, Vice Chairman
Mr. Vance Oyama	Mr. George Clemens
Dr. Robert B. Painter	Mr. Frederick A. Demele
Dr. Laurence I. Hochstein	Mr. Ralph W. Donaldson, Jr.
Dr. Hans J. Trurnit	Mr. Richard O. Fimmel
Mr. Jacob H. Miller	Mr. George H. Holdaway

2. The subject team is responsible for determining the status of each of the proposed life detection experiments from both the science and engineering points of view. Careful attention will be given to what must be done to make each scientific experiment ready for the 1966 mission. The status report and final recommendations resulting from this study will be submitted for Center review not later than August 1, 1963, and they will be submitted to the Office of Space Sciences, NASA Headquarters, not later than August 15, 1963.

/s/ Smith J. DeFrance

Smith J. DeFrance
Director

63/28

COPY

SB(FHQ:cj)

COPY

6 June 1963

AIR MAIL

Dr. Klaus Biemann
Department of Chemistry
Massachussetts Institute of Technology
Cambridge 39, Massachussetts

Dear Dr. Biemann:

The Ames Research Center has been requested by NASA Headquarters to conduct a survey of possible life detection experiments for the proposed 1966 Mars Mariner Mission.

Accordingly, representatives of Ames will visit your institution during the June 17 to 28 time period.

Final dates and arrangements will be made directly from the Ames Research Center.

Sincerely yours,

Original signed by
Freeman H. Quimby

Freeman H. Quimby
Chief, Exobiology
Bioscience Programs
Office of Space Sciences

CC: Code S Reading file
SB/Dr. Reynolds
SB/ Mr. Hall
Mr. C.A. Syvertson, Ames Research Center

Identical letters sent to: Dr. Wolf Vishniac, Dr. Gilbert Levin, Dr. Ira Blei, Dr. George Hobby, Dr. Joshua Lederberg, Dr. Robert D. Allen, and Dr. R. E. Kay.

COPY COPY

June 13, 1963

SPECIAL DELIVERY

Dr. Joshua Lederberg
Department of Genetics
Medical School
Stanford University
Stanford, California

Dear Dr. Lederberg:

Recently you received a letter from Dr. Freeman H. Quimby of the NASA Office of Space Sciences indicating that the Ames Research Center had been requested by NASA Headquarters to conduct a survey of possible life detection experiments for the proposed 1966 Mars Mariner Mission. It was further noted that as part of this survey you will be visited by representatives of Ames during the latter part of June. In general, there will be two representatives making this visit; one will represent life sciences and one physical sciences and engineering. As indicated in Dr. Quimby's letter, the specific arrangements for each visit will be made on an individual basis and generally by telephone.

One of the primary purposes of the visit is to collect information relative to the status and support requirements of each of several experiments. With this information the survey team will attempt to assist the experimenter and the Office of Space Sciences in evaluating what remains to be done to convert each experiment into a flight instrument. In order to expedite the collection of this information and in order to provide a consistent set of information for each experiment, a group of tentative questions to be discussed during the visits has been prepared. Two copies of this group of questions is forwarded with this letter to provide the experimenter with an advance indication of the type of information sought. It is emphasized that these questions will serve only as a guide and are being forwarded primarily to reduce the time required of all parties involved in conducting the survey. If necessary, any of the questions can be clarified during this visit.

It is further requested that, if it is possible and reasonable to do so, a demonstration of each experiment be arranged during the visit.

It should also be noted that, while primary interest at this time is in the 1966 mission, information pertinent to subsequent opportunities to explore Mars is also sought.

Your cooperation in the conduct of this survey will be greatly appreciated.

Very truly yours,
/s/ C. A. Syvertson
C. A. Syvertson
Chairman, Life Detection Experiments Team

CAS:vej
Enc.
Tentative Questions
for Visits (2 copies)

cc: NASA Hq - Code: SB, w/o enc.

SURVEY OF LIFE-DETECTION EXPERIMENTS FOR MARS MARINER 1966 MISSION

I. Scientific Experiment

A. What is your present experiment designed to determine?

B. Does this represent a departure from any previous objectives? If so, why?

C. What are the non-biological systems which, when assayed in your device, might react as if they were biological?

D. What controls are included in your experiment?

E. What is the present and projected sensitivity of your experiment?

F. What is the reference standard in the experiment?

G. What biological materials (e.g., enzymes, substrates, etc.) are used in the experiment?

H. What are the total number of samples your instrument requires?

I. What is the proposed technique and apparatus required for sample acquisition?

J. Does the sample have to be treated in any special way prior to observation?

K. If so, exactly what apparatus and how much material or reagents will be required for such treatment?

L. How many sample-taking, processing and test-result-conditioning cycles will be required to obtain the minimum amount of information to consider the experiment fruitful?

M. What instrument components are used in the experiment?

N. Are all experiment instrumentation requirements satisfiable within the state of the art? If not, what development is required?

O. What will be the weight and volume requirements of all instrumentation (individual weights and volumes also cumulative weight and volume)?

P. Is the function or lifetime of your total instrument, including all individual components, affected by:

(1) Temperature
(2) Radiation
(3) Pressure
(4) Impact and vibration

Q. How will the instrument be sterilized?

R. What will be the susceptibility of the instrument to sterilization by:

(1) 3 cycles of 145° C for 36 hours each?
(2) 1 cycle of 135° C for 24 hours?
(3) 1 cycle of 125° C for 24 hours?
(4) ethylene oxide?

S. Is the instrument suitable for aseptic assembly?

T. What prelaunch, in-flight, and post-handling test and calibration of experimental apparatus, if any, will be required or desirable and how will these be accomplished?

U. How, precisely, will programming and command required for the experiment be accomplished (e.g., startup, sequencing, time identification, etc.)?

V. What will be done to determine reliability figures for the instrument?

W. What are other current problem areas?

II. Measurement Requirements

A. What restrictions and tolerances, if any, must be placed on the physical attitude of the instrument with respect to Mars terrain?

B. For both present and projected minimum detectability levels, precisely how long will be required to take, process, test and condition test results to the point where these results are in suitable form for transmission to Earth?

C. Does the instrument make continuous readings, or does it require a single chamber per reading?

D. What minimum and maximum bit rates will be required to make the experiment fruitful? (This implies what will be required range, accuracy, and resolution of test results to be transmitted.)

E. Can the detection system be saturated?

F. What exactly will be the quality and type of the signal which occurs at the output of the instrumentation?

G. What will the minimum input impedance requirement and tolerance to the interface have to be to handle the signal adequately?

H. What are the precise power requirements of the experiment instrumentation (including environmental control)?

(1) What sort of peak loading can be expected?
(2) What sort of minimum loads can be expected?
(3) What will be the required quality of the power (AC, DC, voltage tolerance, etc.)?
(4) For what periods of time will power be required (i.e., power profile)?

I. Is your instrument susceptible to interference from other spacecraft instruments and equipments?

III. Status and Scheduling

A. From a scientific standpoint, what is the present status of the experiment?

B. From an engineering standpoint, what is the present status of the experiment?

C. When do you expect to be able to demonstrate the functional feasibility of the experiment?

D. By what date do you expect to have the weights and sizes of your instrument reduced to their minimum values?

E. When do you expect to have a flight prototype instrument ready (i.e., a rugged instrument which has been field tested and is scientifically satisfactory)?

F. What is the current manpower situation of the experiment and what additional manpower (numbers and disciplines) will be required to have the prototype instrument ready by Nov. 1, 1964?

G. What is the current funding situation of the experiment and what additional funding will be required to have the prototype instrument ready by November 1, 1964.

APPENDIX B - EXPERIMENT SURVEY RESULTS

The following subappendices recap the information obtained by the survey teams with the aid of the questionnaire reproduced in appendix A. This information is presented precisely as it was obtained in the survey and it is free from comment of the survey teams. The experiments were examined in three areas: (1) the Scientific Experiment, (2) the Measurement Requirements, and (3) the Status and Scheduling. Each subappendix has the following items:

- Scientific Experiment
  - Objective
  - Effect of Non-Biological Systems
  - Controls - Reference
  - Sensitivity
  - Biological Materials Required
  - Sampling
  - Instrumentation
  - Weight and Size
  - Lifetime Effects
  - Sterilization
  - Testing
  - Reliability
  - Programming and Command
  - Problem Areas
- Measurement Requirements
- Status and Scheduling

The subappendix designated for each experiment is:

- B-1 Gas Chromatograph
- B-2 Gulliver
- B-3 "J" Band
- B-4 Mass Spectrometer
- B-5 Measurement of ATP
- B-6 Minivator
- B-7 Multivator
- B-8 Optical Rotation
- B-9 Wolf Trap

B-1 GAS CHROMATOGRAPH

The information on this experiment was furnished by letter from Mr. Robert V. Meghreblian, Chief, Space Science Division of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, July 12, 1963.

Scientific Experiment

Objective:

The present experiment is designed to detect the presence of organic matter in soil samples obtained from the Martian surface. From the returned data it would be possible to deduce that certain types of organic compounds are present and it also may produce highly indicative but not necessarily definitive information concerning the presence of life on Mars. It is a complementary experiment to growth and metabolism experiments. If organic matter is found, this experiment will provide general background information useful for planning future experiments.

It may: (1) detect the presence of any organic matter in soil samples, either biogenic or abiogenic; (2) suggest the presence of life by producing fingerprint chromatograms of the pyrolysis products of known biochemical compounds, either of living organisms, their metabolic products, or the degraded products of dead organisms; (3) indicate the presence of a possible, unknown biochemistry; and (4) provide information on any existing Martian abiogenic organic chemistry.

Preliminary work on the gas chromatography of the volatile pyrolysis products of microorganisms suggests that "fingerprint" chromatograms can be obtained which will identify proteins, lipids, carbohydrates, possibly nucleic acids, and other biochemical compounds. The successful identification of these substances by the gas chromatograph would make the probability of life very high, though not necessarily definitive. In this way, the gas chromatograph could function as a life detector.

If the chromatograms of the experiment were not indicative of any pretested terrestrial materials, interpretation of the data would be made by attempting to duplicate the chromatograms in the terrestrial laboratory under conditions identical to those existing during the performance of the experiment on Mars. This approach would make possible the identification of unexpected classes of organic compounds either biogenic or abiogenic.

In summary, the present gas chromatograph would be designed to: (1) detect the presence or absence of organic matter in a soil sample collected from the Martian surface, regardless of its type or origin; (2) provide data from which the presence or absence of life in the sample may be deduced; and (3) provide data from which at least some of the collected organic compounds could be identified.

Effect of Non-Biological Systems:

Since the gas chromatograph is capable of detecting organic compounds, the characteristic fingerprint chromatograms may make it possible to distinguish between biochemical compounds of the terrestrial variety and other organic compounds.

Controls - Reference:

Controls include calibration samples of known organic materials to be introduced into the instrument just prior to the performance of the experiment. Functional and environmental parameters will be monitored to verify the conditions of the experiment. Reference standard will consist of calibration materials injected prior to experiment.

Sensitivity:

0.1 to 10 micrograms of organic sample.

Biological Materials Required:

None.

Sampling:

A single sample acquired by a roving vacuum aerosolizer is adequate. The crude sample is subjected to a pyrolysis cycle and the volatile degradation products are introduced into the gas chromatograph.

Instrumentation:

Gas tank, gas pressure regulator, separation column, ovens, ionization detector, dynamic capacitor, reed switches, semiconductors, and electronic circuit components. All instrumentation requirements are satisfiable within the state of the art; however, in some cases development is needed to produce flightworthy components.

Weight and Size:

6.7 pounds, 5×5×8 in., 200 cu. in. Does not include sample acquisition.

Lifetime Effects:

The operating temperature range is -20° to +80° C and the survival temperature -50° to +135° C. Radiation may affect the detector, however it is small enough to be shielded. No pressure effects are anticipated. Impact and vibration problems will be met by design compatible with Lander design for impact.

Sterilization:

The instrument is sterilizable with heat soak and ethylene oxide; however, the effects of the 3 cycles of 145° C for 36 hours each have not been evaluated. The instrument is suitable for aseptic assembly to a limited extent.

Testing:

Prelaunch tests consist of: (1) electrometer calibration, (2) programmer sequencing verification, (3) calibration with electronic peak simulation, (4) instrument calibration by downstream injection of a calibration gas sample carried aboard the instrument, and (5) instrument calibration by injection of a test sample.

In-flight and post-landing tests: (1) calibration with peak simulation, and (2) calibration by downstream injection of a gas sample carried aboard the instrument.

Reliability:

To be attained by use of high quality screen parts and from operating history on breadboard, engineering model, and prototype instruments. Actual reliability figures would be supplied by the component statistical group.

Programming and Command:

The command for startup and sequencing will come from the data system. Sequencing may occur internally from an instrument programmer. Time identification can be handled on either side of the instrument-data system interface.

Problem Areas:

None specified.

Measurement Requirements

Orientation with respect to the surface of Mars is minor, dependent on the final configuration of the pyrolysis oven. The total experiment time is not defined. The instrument will immediately supply time and quantity data for each peak as the peaks occur. The instrument performs a repeatable separation function for as many sample cycles as would be required by the experiment. Instrument output may be: (1) Time: pulse or serial binary data, (2) Quantitative: electrometer integrator output with 1 to 10 ohms output impedance or serial binary data from an A to D converter, depending upon designation of interface.

Power requirement, exclusive of external environmental control, is 4.5 watts peak. Shielding of the electrometer compartment will preclude most external interference problems. Also, care must be given to ground referencing to provide adequate isolation.

Status and Scheduling

Preliminary work has been done to establish the basic parameters for the design of the instrument. Pyrolysis temperature cycles have been tentatively set, column types and detectors have been tentatively chosen, and general requirements have been set.

Further studies will be required to more precisely define and verify optimum pyrolysis cycles, columns and detectors. This work could be essentially completed in about two months, prior to breadboard design and could subsequently be coordinated with the breadboard development. Continuation of these basic studies would continue throughout the development and flight during the execution of the mission in order to provide as much information as possible for later data interpretation upon completion of the mission.

A feasibility breadboard has been constructed. Signal processing electronics are in development and detectors are being evaluated. Engineering feasibility could be demonstrated within six months from the date of funding. The scientific feasibility has been demonstrated. Weight may be reduced to minimum value ten months from date of funding. Size may be reduced to minimum value nine months from date of funding. A unit similar to a capsule instrument such as would be flown on a sounding rocket would be available 12 to 13 months from the date of funding in a final, tested configuration. The current manpower is four scientists and engineers and two technicians. The estimated additional requirements for this area are four engineers and five technicians. The present tentative budget is $206,000. Additional FY 64 funding required to produce a flight-type organ gas chromatograph would be $425,000.

B-2 GULLIVER

The information on this experiment was furnished to the Survey Team by Dr. Gilbert Levin of Resources Research, Inc., Washington, D. C., on June 27, 1963.

Scientific Experiment

Objective:

To detect bacterial growth by determining the formation of radioactive carbon dioxide from C^{14} labeled substrates.

Effect of Non-Biological Systems:

None have been observed.

Controls - Reference:

An inhibitor of bacterial growth will be introduced into the growth chamber which should result in a cessation of $C^{14}O_2$ formation. Whether this is accomplished in the same chamber as the growth experiment or in a duplicate Gulliver is a matter for future consideration. A third control to be considered is that of an uninnoculated medium.

Sensitivity:

See tables B-2-A and B-2-B.

Biological Materials Required:

C^{14} labeled glucose, formate, lactate, and glycine.

Sampling:

A single untreated sample per instrument is required. The sample is acquired on a length of chenille, attached to the end of a line which is ejected from the instrument. The line is dragged across the surface to collect soil particles which are introduced with line and chenille into the growth chamber.

Instrumentation:

Sample-collecting mechanism, a main chamber containing the sample processing mechanism, a radiation counter, an electronic signal and data processing system, an ellectronic programmer, and a heater. All requirements are within the state of the art. Engineering developments are required. The system consists of two individual instruments of which one is used as a reference standard. Components such as the programmer and logic and data-handling system will be common to both instruments.

Weight and Size:

One instrument weighs 1-1/2 pounds and is 4x4x6 in., 96 cu. in. Two instruments weigh 3 pounds and are 4x8x6 in., 192 cu. in. The programmer weight is 1-1/2 pounds. The logic and data handling system weighs 2-1/2 pounds. A minimum total weight is 7 pounds. A maximum total weight with a more elaborate detector system weighs 12 pounds. System volume having two instruments, programmer, one logic and data handling system would be 404 cu. in. The estimated maximum value based on the more elaborate detector system is 600 cu. in.

Lifetime Effects:

Not affected by temperature, radiation, pressure, impact or vibration. Incubation chamber and sample have to be kept above the freezing point.

Sterilization:

Proposed methods present no problem. The instrument is suitable for aseptic assembly.

Testing:

Prelaunch test of the radiation detector and electronics is planned by means of the introduction of a small radio-active source.

Reliability:

To be essentially the same as AMF is using on other space programs.

Programming and Command:

The built-in programmer will control all the sequencing after a start signal is provided by the spacecraft after landing.

Problem Areas:

No major problem areas foreseen; however, detailed interface information will be required to effect mating with spacecraft.

Measurement Requirements

Orientation of Gulliver with surface of Mars is immaterial, however, the sample collecting mechanism will require an attitude orientation not yet defined.

The instrument makes continuous readings. The minimum requirement is two points, each described by two words of a 15-bit length. High-intensity signals such as solar flares or a high level of radioactive CO_2 in the Martian atmosphere could cause saturation of the detection system.

The power requirements may be supplied with a low voltage DC with about ±10 percent tolerance to provide a normal power consumption of 2 to 3 watts with a peak demand of 4 to 5 watts for 2 minutes. In addition, approximately 2-1/2 watts is required for heaters for below-freezing temperatures. The type and quality of the signal and the output impedance will be compatible with the spacecraft interface requirements. No interference problems are anticipated.

Status and Scheduling

An advanced feasibility model was demonstrated in November 1962, and in a field test June 27, 1963.

Weights and sizes will be determined approximately six months after the start of a contract calling for a flight-prototype model. One year from the start of a production contract is required to complete the flight prototype instrument.

The present manpower effort consists of 4-1/2 people. It is estimated that 10 people will be required to complete the prototype in one year.

The present AMF contract is for about $84,980. The funding requirements for a contract to deliver a flight-prototype instrument within a year will be between $250,000 and $350,000, depending on the interface requirements and whether it is decided to include a photosynthesis experiment and a sterile control in Gulliver.

Resources Research, Inc. would like an additional $50,000 above current level of support so as to support: (1) full-time engineer, (2) 1/2-time biologist, and (3) a full-time technician, and (4) to obtain additional materials.

TABLE B-2-A

SOME GENERAL CHARACTERISTICS OF

SOIL ISOLATES

Isolate	Soil source	Type	Gram stain	Characteristics
A	Field & Garden	Bacterium	Gram positive bacillus	White, lacy colonies growing in swirl arrangement.
B	Field	Bacterium	"	Small, circular, opaque colonies.
C	Garden	Bacterium	"	Pale yellow, distinct colonies.
D	Field	Bacterium	"	Dull, white colonies producing brown pigment in the medium.
E	Field & Garden	Fungus	"	Green changing to dark brown mycelial growth, Pencillin-like.
F	Field & Garden	Fungus	"	White mycelial growth.

TABLE B-2-B

Response to M8 Medium

Sample	Cells per test	C-14 substrate	Radioactivity-CPM above sterile control				
			Time in hours				
			0.5	1	2	4	8
Soil Isolate A bacterium	66,000	1	2,145	3,390	6,350	12,970	19,900
Soil Isolate B bacterium	29,800 59,600	1 1	30 165	80 240	375 735	2,235 4,335	6,790 8,790
Soil Isolate C bacterium	3,700,000 7,400,000	1 1	0 65	0 65	0 165	120 420	490 890
Soil Isolate E bacterium	118 177	1 1	75 165	345 465	590 585	1,290 1,590	3,360 5,160
Soil Isolate F Fungus	58,400 87,600	1 1	50 110	120 150	270 330	1,120 1,350	4,590 4,590
Rhodospirillum rubrum (photo-synthetic growth)	220,000	2	120	180	360	940	1,545
Rhodospirillum rubrum (non-photosynthetic)	181,000	2	1,040	1,615	2,485	4,430	8,270
Bacillus subtilis var. globigii	70,000	1	65	135	405	2,060	11,800
Pseudomonas fluorescens	228,000	2	130	135	315	450	800
Garden Soil	112,865	3	2,260	4,030	8,890	16,345	20,520
Garden Soil	112,865	4	4,342	7,170	13,010	18,893	22,180
Field Soil	88,730	4	585	1,225	2,340	5,430	10,625
Field Soil	88,730	3	560	1,015	2,405	5,019	9,450

1. Formate-(1.0 μM) + Glucose (0.33 μM)
2. Formate-(0.66 μM) + Glucose (0.22 μM) + Lactate-(0.44 μM)
3. Formate-(0.66 μM) + Glucose (0.22 μM) + Malic-(0.44 μM)
4. Formate-(0.66 μM) + Glucose (0.22 μM) + Glycine-(0.44 μM)

B-3 "J" BAND

The information on this experiment was furnished to the Survey Team by Dr. R. E. Kay of Aeronutronic Division, Ford Motor Company, Newport Beach, California, on June 25, 1963.

Scientific Experiment

Objective:

To detect and distinguish between proteins and nucleic acids by observing the shift of absorption bands of thiocarbocyanine dye as produced by macromolecules of proteins and nucleic acids.

Effect of Non-Biological Systems:

High salt concentrations in a soil sample will produce the effect, however, it may be adequately suppressed using 10% Ethanol solutions, as well as by increasing the sample cell temperature.

Controls - Reference:

The use of a pyrolized and/or oxidized soil sample extract as a control in a reference cell. Reference is obtained by dye samples in a solution in both a test and reference optical beam to determine a zero null. Alternatively, a standard such as polyglutamic acid will be employed at the conclusion of the determination.

Sensitivity:

One gamma of biologically important macromolecules.

Biological Materials Required:

None

Sampling:

A single sample of soil which is processed by extraction, drying and either pyrolized or dialyzed and checked for conductivity within the proposed experimental system is required. The sample acquisition mechanism needs further work. One complete cycle is a minimum; however, recycling is planned to be internal to the experiment with a possibility of using two different temperatures.

Instrumentation:

Spectrophotometer-double beam-optical null, light source, detector, amplifiers, sample processor. The instrumentation is attainable within the state of the art.

Weight and Size:

Minimum weight and volume has not been determined.

Lifetime Effects:

None anticipated from temperature, pressure, radiation or impact and vibration.

Sterilization:

May be sterilized with spacecraft and entry capsule, dye will be contained in a separate sterile capsule. Aseptic assembly is not applicable.

Testing:

Post-landing calibration only, checkout for signal output and communication.

Reliability:

Derived from detailed testing and computational examination of performance pre-flight qualification testing.

Programming and Control:

A signal from the capsule is required for the start and a signal is required to read out data which can be internal to the experiment or obtained from the capsule system.

Problem Areas:

More testing is required to determine finer distinctions between classes of macromolecules and among specific molecules within a class.

Measurement Requirements

Orientation with the surface of Mars is independent as presently conceived. Experiment time is a one-hour maximum with ten minutes for the first cycle. A single chamber is used at 2 to 3 temperatures, repeat samples for follow-on tests to higher extract concentration, no continuous readings. Data requirement specified as a minimum of 10 bits, an optimum of 90 bits, and a maximum desirable of 250 bits total. Interference from the spacecraft is not expected to be a problem. The output signal will be digital.

The power requirements are stated as 28 ± 3 volts D.C. and 400 cycles per second A.C. for a peakload of 5 amps, 28 volts for 10 milliseconds, average power 2-3 watts for one hour and about 10 watts to survive the Martian night.

Status and Scheduling

Progress in determining presence of either proteins or nucleic acids at the 1 gamma level is good. Progress looks promising to discriminate between proteins and nucleic acids.

The engineering aspects of the experiment are conceptual only. To demonstrate functional feasibility would require an engineering functional breadboard plus six months.

It is estimated that a flight qualified prototype could be available by November 1964.

Present manpower is 3 scientists. Required manpower is 6 man years of science, 8-10 man years of engineering, and 3 months for test and evaluation.

Current funding is $99,000 for science for one year. Required funding is $400,000 for 12 months of engineering and $100,000 for 12 months of science.

B-4 MASS SPECTROMETER

The information on this experiment was furnished to the Survey Team by Dr. Klaus Biemann at the Massachusetts Institute of Technology, Cambridge, Massachusetts, June 20, 1963.

Scientific Experiment

Objective:

To show the presence or absence of biologically occurring molecules by obtaining a mass spectrogram for interpretation. All amino acids and many hetrocyclics, as well as the inorganic atmospheric materials, are analyzed.

Effect of Non-Biological Systems:

None

Controls - Reference:

None except for machine operation.

Sensitivity:

Fractions of a microgram (1 microgram to 1 nanogram). The projected miniaturized mass spectrometer will have a range of 0-250 mass units and may be operated in the range of 0-160 mass units.

Biological Materials Required:

None

Sampling:

One sample is required. No sampling technique has been devised. The sample must be ground, placed on the tube filament, degassed, and heated by the filament. The tube must be evacuated after the sample has been inserted.

Instrumentation:

Miniaturized mass spectrometer vacuum pump, sampling device, electronics, and analog to digital converter. The instrumentation is within the state of the art.

Weight and Size:

Expected total weight is 15 to 25 pounds with a 1.5 pound vacuum pump and 5 pounds for the analog to digital converter. Total volume is about 400 cu. in. consisting of spectrometer-190 cu. in., electronics-110 cu. in., and vacuum pump-110 cu. in.

Lifetime Effects:

Temperature, radiation, impact and vibration have no effects. Pressure in the tube must be reduced to a vacuum after sample is inserted.

Sterilization:

Can be sterilized by either method. Sterilizability of electronic components is questionable. The instrument is suitable for aseptic assembly.

Testing:

Post-landing measurements prior to analysis: ionizing current, voltage applied to filament, voltage applied to the electronics package, sample temperature, and filament temperature.

Reliability:

Reliance on NASA to determine reliability. Instrument will be designed and tested in accordance with applicable NASA specifications.

Programming and Command:

A time cycle is projected. Start of experiment must be determined by capsule.

Problem Areas:

Introduction of sample at a remote location and sensitivity increases.

Measurement Requirements

Orientation with the surface of Mars is not required. Discrete data with an accuracy of ± 10% is desired and expected maximum requirements is 2000 bits.

The power requirements, from 28 ± 3 volts D.C., is a minimum of 0.5 watt and a maximum load of 10 to 12 watts distributed as follows: vacuum pump and analog to digital converter 7 watts, electronics 0.5 watt, filament - remainder of power.

Interface requirements need to be defined.

Status and Scheduling

Functional feasibility has been demonstrated with large-scale mass spectrometers. A 22-pound mass spectrometer has been manufactured. It is estimated that a prototype breadboard unit can be made available for test six months after a starting date and that weights and sizes can be reduced to a minimum 9 months after a starting date.

The present experiment has four personnel assigned; two additional technical assistants and the services of Consolidated Systems Corporation will be required for fabrication of the instrumentation.

The breadboard model will cost $50,000 and the completely tested and fabricated space instrument will be delivered for additional $200,000.

B-5 MEASUREMENT OF ATP

The information on this experiment was furnished to the personnel of the Exobiology Division at Ames by Dr. Gilbert Levin of Resources Research, Inc., Washington, D. C., on July 12, 1963.

Scientific Experiment

Objective:

To determine the presence of ATP on Mars as a probable indicator of life. It has been demonstrated that earth microorganisms can be detected by virtue of their ATP content.

Effect of Non-Biological Systems:

None are known.

Controls - Reference:

A non-innoculate control.

Sensitivity:

10^{-4} micrograms ATP permitting the detection of approximately 4000 yeast cells or 5000 algae, an improvement of one order of magnitude is hoped for.

Biological Materials Required:

Luciferin, luciferase, sample, magnesium (Mg^{+2}) and oxygen.

Sampling and Sample Treatment:

The sample may be obtained by high volume sampling of the atmosphere during descent or with a sampling apparatus similar to Gulliver after landing.

The sample might be treated with methanol, or another solvent, to extract the intra-cellular ATP. A one- or two-minute extraction would probably increase sensitivity to a positive determination with 500 or 1000 cells.

A single sampling and processing is required for data. A processing would be required for sterile control and an early reading of light in the chambers to detect possible leakage would be helpful. Processing consists of the extraction and a rapid mixing of the sample material with luciferin and luciferase.

Instrumentation:

A sample collection device, an extraction device, a processing device, and a photomultiplier tube. Instrumentation is commercially available. No attempts to reduce size and weight have been made but there are no apparent obstacles.

Lifetime Effects:

High temperature would adversely affect the enzyme luciferase. Radiation effects, impact, and vibration have not been explored. Pressure problems not anticipated.

Sterilization:

The instrument could probably be sterilized with the exception of the enzyme which could be sterilized by membrane filtration or other cold methods. The instrument is suitable for aseptic assembly and the enzyme could be introduced after the spacecraft were readied.

Testing:

Tests for sensitivity to light at pre-launch, in-flight and post-landing and a post-landing absence of light due to leakage are desired.

Realiability:

No determinations.

Programming and Command:

Not determined.

Problem Areas:

Obtaining an adequate sample during descent if this mode is used.

Measurement Requirements

The experiment requires no orientation with respect to the surface of Mars. Total experiment time whether in the atmosphere or on the surface would be 5 to 7 minutes. The instrument could be used to make a controlled reading, or several control readings, but only one reaction response reading for the total experiment. A bright light source would saturate the detection system. Power requirements and type of output have not been defined; however, it is expected that the phototube output would produce 3 or 4 discrete pulses for the complete experiment.

Status and Scheduling

The experiment has been demonstrated successfully in the laboratory on earth organism. The instrumentation has been assembled and operated; however, no work has been done toward producing an exobiological experiment nor is there any program to do this.

Approximately five people are working on this method for other purposes than detection of extraterrestrial life.

At present no funds are available for this project, but a very rough estimate of $100,000 was made to cover the scientific investigation and associated instrumentation for an advanced breadboard or prototype by Nov. 1, 1964.

B-6 MINIVATOR

The information on this experiment was furnished to the Survey Team by Mr. Jerry Stuart of Jet Propulsion Laboratory, Pasadena, California, on June 24, 1963.

Scientific Experiment

Objective:

Minivator is designed to provide a sampling device and processing and sample chambers in which experiments may be conducted.

Effect of Non-Biological Systems:

C_aCO_3 in dust form shows fluorescence.

Controls - Reference:

A reference cell employed without a soil sample.

Sensitivity:

No determination.

Biological Materials Required:

No determination.

Sampling:

A gas turbine driven dust collector stirs up and collects the sample, then performs a centrifugal large particle separation. Sample should be placed in solution.

Instrumentation:

Sample collector, minivator which contains a phototube, sample chambers and liquid reservoir.

Weight and Size:

Sample acquisition tubing and injection mechanism 0.25 pound, gas bottle - 2 pounds, minivator - 1.5 pounds, electronics - 1 pound. Total weight - 5 pounds. Size not given.

Lifetime Effects:

Not determined, no problems anticipated.

Sterilization:

The proposed methods present no problems. The instrument is suitable for aseptic assembly.

Testing:

No information.

Reliability:

No information.

Programming and Command:

No information.

Problem Areas:

(1) Low power, high efficiency ultraviolet lamps; (2) electric D.C. motors; (3) bearings for low pressure atmospheres; (4) uniformity of miniature incandescent lamps; (5) cell material that is opaque, machinable, non-permeable to fluids, and with a resistivity of about 10^{11} ohms.

Measurement Requirements

Orientation with surface of Mars must be restricted from horizontal to 20 degrees. The instrument makes repetitive readings on 16 chambers. It is estimated that is would take a few days to two weeks to get results which are suitable for transmission to earth. The detection system can be limited by the light source.

Power requirements, minimum loads at 1-2 watts, maximum loads at 5-10 watts. Maximum power requirement is for providing heat during the nights.

Signal outputs will be 0-5 volts analog. Interference is not anticipated as a problem.

Status and Scheduling

Work has been done on the sample collecting techniques combined with Multivator.

A Minivator would have to be designed for a particular group of biochemical experiments after they have been designated. Thereafter, a 6-9 month period might be required to perfect hardware systems.

The present manpower consists of 1-1/2 engineers and 2 technicians. Total manpower requirement is 3 engineers and 4-5 technicians.

Funds required: For further laboratory prototype testing - $30,000; for first flight qualified prototype - $150,000; for test and evaluation equipment - $40,000 -- Total - $220,000 plus a bacteriologically clean room. Follow-on units at $50,000-$60,000 each.

Funds required for '66 mission would require a crash science program of at least $500,000, probably more funds would be required.

B-7 MULTIVATOR

The information on this experiment was furnished to the Survey Team by Dr. J. Lederberg, Department of Genetics, Medical School of Stanford University, Stanford, California, on June 27, 1963.

Scientific Experiment

Objective:

To determine enzymatic activity.

Effect of Non-Biological Systems:

None.

Controls - Reference:

A reference cell is employed without a soil sample.

Sensitivity:

Present, approximately 10^5 organisms per cc; projected, approximately 10^2 per cc.

Biological Materials Required:

No biological material as such. Enzymatic activity or phosphate fluorescein derivative.

Sampling:

A double sample immersed in liquid is minimum requirement. The sample is acquired by vacuum cleaning.

Instrumentation:

Multivator, 2 cc of water. All instrumentation is within the state of the art.

Weight and Size:

Multivator - 1 pound, 45 cu. in.; Collector - 1-2 pounds, 40-50 cu. in.

Lifetime Effects:

Not affected by radiation, pressure, impact, or vibration but temperature must exceed 0° C.

Sterilization:

Suitable for either method. Chemicals must be added aseptically after sterilization.

Testing:

Calibration built in.

Reliability:

To be determined by extensive testing.

Programming and Command:

Start-up from external signal: Sequencing and timing may be internal to multivator or on board spacecraft.

Problem Areas:

None specified.

Measurement Requirements

Orientation with respect to the surface of Mars is not required. Length of test is one hour, detectivity increases linearly with time. Measurements will be sampled and presented as an analog voltage of 0-10 volts. Minimum input impedance must be greater than 10,000 ohms and tolerance to interface must be within ± 10%.

The instrument requires AC and DC with built-in regulation. Power requirement is 3-5 watts for sample gathering 1-5 minutes then 1 watt for 90 seconds every 15 minutes. Instrument is not susceptible to interference.

Status and Scheduling

The first phosphatase detection substrate that shows any reasonable stability was achieved June 1963. More testing is required.

The flight size breadboard is existing and minimum weights and sizes can be determined by September 1963. A flight prototype instrument can be ready by January 1964, depending upon spacecraft integration requirements.

Stanford has personnel available. A commercial contract will require 5-8 man years.

Funding for science studies has been requested of NASA Headquarters by Dr. Lederberg. Funding for engineering with a commercial concern would be $200,000 - $300,000.

B-8 OPTICAL ROTATION

The information on this experiment was obtained by the Survey Team from Dr. Ira Blei, Dr. John Liskowitz, and Mr. Sol Nelson of Melpar, Inc., Falls Church, Virginia, on June 28, 1963. Confirmation of these data was obtained from Dr. Liskowitz on July 8, 1963.

Scientific Measurements

Objective:

To determine the presence of optically active compounds at 254 millimicrons.

Effect of Non-Biological Systems:

None.

Controls - Reference:

A quartz plate, of known optical rotation, will be introduced into the light path. This calibration will serve to establish a base line as well as serving to establish the functioning of the instrument.

Sensitivity:

10^4 - 10^5 organisms.

Biological Materials Required:

None.

Sampling:

No sampling method has been developed. One sample per analysis is required. Processing is required; after collection, the sample will be extracted with an alkaline solution, probably 1N sodium hydroxide. Following extraction the solution will be clarified and then introduced into the chamber for observation.

Instrumentation:

A pump, a device to clarify the extracted soil from the soil extract, and an alkaline solution. Equipment consists of optics unit, electronics unit, sample processor, pneumatic supply, programmer, squibs and exothermic cartridges, and module frame. All instrumentation is within the state of the art.

Weights and Size:

Total weight is 5.20 pounds and volume is 130 cu. in. Optics 72 cu. in., 3 pounds; Electronics 14 cu. in., 0.40 pound; Sample Processor 14 cu. in., 0.50 pound; Pneumatic supply 14 cu. in., 0.50 pound; Programmer 14 cu. in., 0.40 pound; Squibs and exothermic cartridge 2 cu. in., 0.10 pound; Module frame 0.30 pound.

Lifetime Effects:

Radiation, pressure, impact and vibration impose no problems; however, the temperature must be above the freezing point of the liquids.

Sterilization:

Ethylene oxide will be used; heat method poses no problems. The instrument is suitable for aseptic assembly.

Testing:

Pre-launch and post-landing tests will be required but have not been defined.

Reliability:

To be determined by component review and an environmental test program.

Programming and Control:

A start pulse will be required from spacecraft, remaining control is contained in instrument.

Problem Areas:

Interface with spacecraft not clearly defined.

Measurement Requirements

Orientation with respect to the surface of Mars is not necessary. Time for a complete experiment is 415 seconds. The instrument requires a single chamber per reading. Measurements may be voltage levels in the range 0-1 volts, resolution requirement is 1 millivolt and accuracy should be ± 1%. Instrument can be simplified to a simple yes-no signal. The detection system cannot be saturated.

Minimum input impedance requirement to the interface is 10,000 ohms ± 10.

Power requirement peak is 1.1 watts, and minimum 0.15 watt from 28 volts DC ± 10%.

Interference is not considered to be a problem.

Status and Scheduling

The theoretical development for measuring optical rotation has been proven experimentally. Equipment has not been reduced in size or weight or been subjected to environmental conditions.

Manpower and funding status and requirements are referred to the PERT chart of Melpar Proposal No. P 314.111, May 1963.

B-9 WOLF TRAP

The information on this experiment was furnished to the Survey Team by Mr. C. R. Weston of the University of Rochester, Rochester, New York, on June 25, 1963. Supplementary information was obtained from H. E. Poyer of Ball Bros. on July 2, 1963.

Scientific Experiment

Objective:

To detect the growth of organisms by light scattering measurements and by change in pH. The principal criterion for growth is a logarithmic increase in the amount of scattered light. An accompanying pH change would strengthen inference that no change in light response resulted from biological growth.

Effect of Non-Biological Systems:

None

Controls - Reference:

No final decision has been made. Two types of controls are planned; an inoculated blank (i.e., a non-nutrient medium, perhaps only water) and an inoculated replicate to which has been added some germicidal agent such as formaldehyde.

Sensitivity:

10^7 organisms per milliliter by turbidometric measurements. Commercial nephalometers are readily capable of detecting approximately 10^5 organisms per milliliter.

Biological Materials Required:

Ethanol, glucose, sodium glutamate.

Sampling:

One sample is required for each chamber. Thirteen chambers, including controls but not allowing for replication, are anticipated. The sample is to be collected in a gas stream and "scubbed" in the medium.

Instrumentation:

Gas pressure supply, a flexible tube with an enclosure shroud to be dropped to the surface, and a venturi nozzle which will provide a pressure differential. The velocity of a low pressure return will induct the sample which will be metered. Instrument components consist of lenses, source lamps, silicon cell photodetectors and metallic bellows. The electronics will contain Fairchild 2N2484 class transistors, carbon resistors, ceramic capacitors and silicon semiconductors. The electronics are all state of the art. The photodetection for forward scattering must be developed for resolution and stability. The pickup device must be developed for Martian atmosphere.

Weight and Size:

A five cell system is estimated at 5.0 pounds. A single cell system should weigh 2.5 pounds. The sample acquisition device will serve either a single cell or five cells. Volume for five cells is about 200 cu. in. and for a single cell about 150 cu. in.

Lifetime Effects:

Safe limits for experiments are:

(1) Temperature: -50° F to $+310^{\circ}$ F
(2) Radiation: Total flux density of 1×10^{7} roentgen
(3) Pressure: Vacuum to several atmospheres
(4) Impact: The source lamp will limit shock loading to 2000 g at 5 milliseconds.
(5) Vibration: The unit will be designed to withstand normal vibration inputs for boosters such as Atlas or Thor Delta.

Sterilization:

Instrument will be sterilized by a terminal heat 3 soak of 135° C for 24 hours. Ethylene Oxide not anticipated. Unit is suitable for aseptic assembly but this method is rejected by experimenter.

Testing:

Prelaunch, in-flight, and post-landing tests are required but have not been defined.

Reliability:

To be determined by normal quality control methods, reliability study on components, model testing, and extreme thermal tests to accelerate failure modes.

Programming and Control:

The start signal from the spacecraft is required. Programming is internal, control may also be external.

Problem Areas:

Since work has not started, there are many problem areas. The principal problems lie in the resolution of the detector system and in the reliability of the sample acquisition device.

Measurement Requirements

Orientation with respect to the surface of Mars will be required. Instrument will be gimbal mounted so as to have 45^{o} of freedom from local vertical. This will be restricted by the necessity of being able to either drop the pickup device to ground surface or cast it clear so that it will reach ground.

A minimum time of ten hours of operation is required. Continuous power will be required for five minutes to acquire the sample, thereafter, if readings are intermittent when power is on, several seconds will be required for the lamp to stabilize and then an analog reading may be taken.

Intermittent readings once every 15 minutes for ten hours are suitable. Each telemetry output will consist of five analog readings, eight bits per reading. Signal output will be analog 0-5 volts. Maximum input impedance should be about 5,000 ohms ± 20%.

Power requirements using DC, greater than 6 volts ± 20% are 1 watt for peak load, 100 milliwatt minimum load and 250 milliwatt average load.

Detector saturation is not anticipated.

Interference problems require decoupling from the normal power line transients and shielding for R. F. interference.

Status and Scheduling

The principles of detecting growth of microorganisms by an increase in turbidity of the nutrient medium, and the principles of enrichment culture for organisms with special nutritional requirements have a large existing literature. Some work has been done with commercial instruments to anticipate the parameters of the experiment.

Six months after the program is funded, it is expected that functional feasibility, weight and size reduction can be demonstrated. A flight prototype instrument could be ready by April 1965, if work started in September 1963.

Manpower at the University of Rochester is one Ph.D full time, one Ph.D 20% time, one technician half time. Required effort for November 1964 delivery, 1 Ph.D full time, four technicians full time.

Current funding is adequate. Twice present funds are required for November 1964 delivery.

TABLE I.- STATUS AND SUPPORT REQUIREMENTS FOR EXPERIMENTS

Experiment	Current status	Date available	Manpower support to meet '66 date	Monetary support to meet '66 date	Comments
Gas chromatograph	Feasibility breadboard	Nov. 1964	Additional: 4 engineers and 5 technicians	$425,000	
Mass spectrometer	Conceptual	May be ready 1966 launch date	Two assistants for Dr. Biemann and the services of Consolidated Systems Corp.	$350,000	Support requirements appear to be underestimated by experimenter
Vidicon microscope	Science - Conceptual Device - None	?	?	?	Data rate requirements demand power available only with much larger boosters. Development of sample handling and methods for discrimination of biologicals requires more work.
Multivator	Science - Functional feasibility Device - Flight sized breadboard	? Sept. 1, 1963	Sufficient available Sufficient available	Sufficient available $10,000 for development of "Mark II" $200,000 for flight hardware	Depends on stability of phosphatase assay substrate Can accommodate wide variety of biochemical experiments including some already proposed
Minivator	Science - None Device - Flight sized breadboard	- Now	- 3 engineers 4 technicians	- $200,000 for flight prototype, $40,000 for test and evaluation	Science input lacking; accommodation similar to Multivator
"J" band	Science - Functional feasibility Device - Conceptual	Aug. 1, 1963 Aug. 1, 1964 for flight prototype	2 scientists 4 technicians 8-10 people 1 yr	$100,000 $300-400,000	Sample acquisition and handling development not begun
Gulliver	Advanced breadboard demonstrated. Ready to start work on prototype	With proper funding and interface definition 1 year from contract award	10 people will be required in the engineering area	Between $250,000 and $350,000 depending on required experiment configuration	
Wolf trap	Lab feasibility model. Engineering is conceptual.	April 1963	Univ. of Rochester will need 1 Ph.D. and 4 techs. Subcontractor requirements unknown.	Double present funding	
Optical rotation	Some functional feasibility demonstrated	14 months from a contract start	-	$274,652	

TABLE II.- SUMMARY OF ENGINEERING REQUIREMENTS FOR EXPERIMENTS

Experiment	Weight, lb	Volume, cu in	Power required, av/peak, watts	Possible lifetime	Recording time	Data type	Sterilizable by 300° F for 24 hr	g tolerance	Required measurements min/max	Total bits at 7 bits per meas. min/max
Gas chromatograph	6.7	200	?/14.5	Undefined	Undefined	Analog or digital	Yes	Undefined	Continuous	Undefined
Gulliver	7-12	300-600	2-3/4-5	Undefined	Undefined	Digital	Yes	100	2/100	14/700
"J" band	Undefined	Undefined	2-3/10	Weeks	< 1 hr	Digital	Yes	Undefined	18/54	126/378
Mass spectrometer	15-20	400	?/10-12	Months	Minutes	Analog	Yes	Undefined	250/750	1750/5250
ATP	Undefined	Undefined	Undefined	Undefined	5-7 min	Analog	Yes	Undefined	4/-	28/-
Minivator	5	Undefined	1-2/5-10	2 weeks	2 weeks	Analog	Yes	Undefined	16/960	112/6720
Multivator	3	95	0.5/3-5	Days-week	1 hr	Analog	Yes	Undefined	60/600	420/4200
Optical rotation	5.2	130	0.5/1.1	Undefined	Undefined	Analog	Yes	Undefined	1 after 45 sec	7/7
Vidicon microscope	Undefined	Undefined	10	Undefined	Undefined	Analog	Undefined	Undefined	5 pictures	35×10^5
Wolf trap	2.5-5	150-200	0.25/1	10 hrs min	10 hrs	Analog	Yes	2000 for 5 sec	40/cont	280/-

TABLE III.- SUMMARY OF VEHICLE SYSTEMS CAPABILITIES

Vehicle system	Weight to Mars, lb	Capsule weight, lb	Guidance and control weight, lb	Structures and heat-shield weight, lb	Terminal deceleration weight, lb	Power system weight, lb	Communication system weight, lb	Experiment payload, lb	Payload volume, cu ft	Maximum loading, earth "G"	Power radiated, watts	Data transmission rate, bits/sec	Lifetime	Sterilization requirement, temp-time	Total data transmission, bits
Atlas-Agena Flyby	450	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Atlas-Centaur Flyby bus plus capsule Dir. comm.	1204	352	45	205	52	28	37	30	2-3	200	36	6	30 hr	300° F - 24 hr	32,400
Relay comm.	1254	369	78	215	54	34	36	30	2-3	200	45	6	40 hr	300° F - 24 hr	32,400
Bus plus capsules	980	176	0	84	27	23	27	15	~1	140	75	1	48 hr	260° F - 26 hr	5,400
Saturn I	3200	1500	65	270	140	275	225	525	~10	90	100	8800	1 mo	300° F - 24 hr	Very large
Saturn I-B	6000	3500	115	550	275	275	245	2040	~40	90	100	8800	3 mo	300° F - 24 hr	Very large

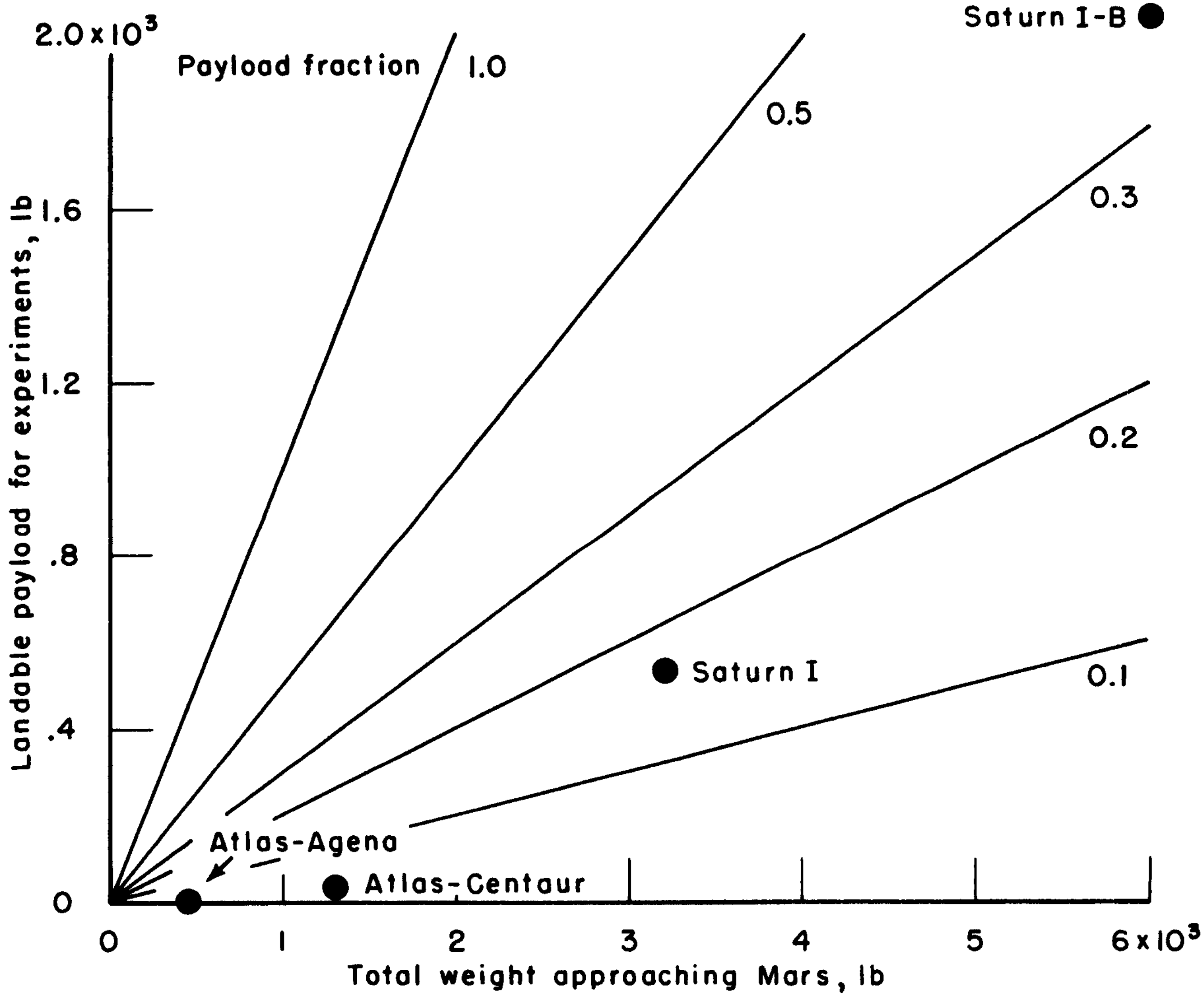

Figure 1.- Payload capabilities of various spacecraft systems.

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